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CONTRACT NUMBER DAMD17-94-C-4082

TITLE: Increasing the Accuracy of Mammogram Interpretation

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REPORT DATE: October 1997

TYPE OF REPORT: Annual

PREPARED FOR: Commander
U.S. Army Medical Research and Materiel Command
Fort Detrick, Frederick, Maryland 21702-5012

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19980611 089

REPORT DOCUMENTATION PAGE			Form Approved GSA No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1997	3. REPORT TYPE AND DATES COVERED Annual (15 Sep 96 - 14 Sep 97)		
4. TITLE AND SUBTITLE Increasing the Accuracy of Mammogram Interpretation		5. FUNDING NUMBERS DAMD17-94-C-4082		
6. AUTHOR(S) John A. Swets, Ph.D.				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) BBN Technologies GTE Internetworking Cambridge, Massachusetts		8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Research and Materiel Command Fort Detrick Frederick, Maryland 21702-5012		10. SPONSORING/MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200) The project's aim is to refine and evaluate clinically a computer-based system to provide decision support to the radiologist in interpreting mammograms, and generate automatically a standardized report of the mammogram findings to the referring physician. In Year 3, representative case sets of mammograms and clinical data, with pathology or follow-up, were finally assembled at the Brigham and Women's Hospital (referral setting) and at Harvard Pilgrim Health Care (a screening setting). Five BWH radiologists read their 200 cases to provide scale values for each of a checklist of perceptual features, in order to train a set of statistical prediction rules. Five HPHC readers have performed a baseline reading of their 150 cases, as a comparison for the aided readings to be made in Year 4. The automated report writer was brought to a stage suitable for evaluation by a focus group of referring physicians in Year 4.				
14. SUBJECT TERMS Mammography, Perceptual Feature Analysis, Computer-Assisted Diagnosis, Automated Reports, Increased Accuracy, Quality Assurance, ROC Analysis, Screening and Referral, Breast Cancer			15. NUMBER OF PAGES 60	
17. SECURITY CLASSIFICATION OF REPORT Unclassified			18. PRICE CODE	
18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified		19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT Unlimited

NSN 7540-01-280-5600

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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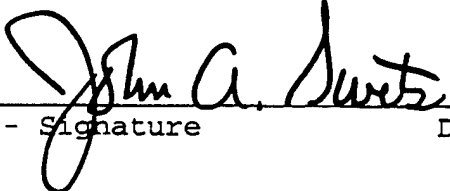

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INTRODUCTION

The aims of the study are to develop a computer-based system that will aid the radiologist in interpreting mammograms, automatically provide a standardized report of mammogram findings to a referring physician, and construct a database of results to help assure the quality of the interpretive process.

In a completed system, the radiologist will assign a rating-scale value to each of a set of perceptual features that have been statistically determined to be diagnostically relevant and comprehensive. Spoken scale values will be recognized by the system, merged optimally (in terms of their predictive weights and intercorrelations) to yield an estimate of the probability of malignancy, and analyzed interactively to generate automatically a prose report using the lexicon of the American College of Radiology. A database organized about the perceptual features will help to resolve differences in dual readings, to construct tutorial materials tailored to individual radiologists, and to adjust thresholds for recommendations of follow-on imaging or therapy.

Five mammographers at Brigham and Women's Hospital (BWH) have assigned ratings to a large set of perceptual features for 200 proven BWH cases both to determine a necessary and sufficient set of features and to "train" a statistical prediction rule to estimate the probability of malignancy as based on feature ratings. Five radiologists at Harvard Pilgrim Health Care (HPHC) will assign ratings to features in a set of 150 proven HPHC cases to "test" the statistical prediction rule. The mammograms thus interpreted at HPHC -- with the aid both of the list of perceptual features and the probability estimate of malignancy -- will be compared to baseline interpretations of the same cases obtained there earlier from the same radiologists, in order to determine the gain in accuracy

provided by the computer-based aid. Reports of mammogram findings generated automatically by the system for selected cases will be assessed by a group of referring physicians and surgeons relative to reports dictated for those cases in the usual way.

This project builds on work done previously in the BBN laboratory to increase accuracy and extends it into the clinic of both a referral center (BWH) and screening site (HPHC). It extends previous work to incorporate the reporting process.

The statistical prediction rule developed earlier led to significant accuracy enhancements and has now been refined in certain ways, principally by considering changes in the perceptual features from prior to current mammograms. The linear-discriminant analysis used earlier as the technique to create the rule was replaced by the logistic-regression technique.

We made assessments of accuracy by ROC analysis (relative, or receiver, operating characteristic) to obtain an index of accuracy that is unaffected by an observer's decision threshold and by the relative frequencies (prior probabilities) of malignant and non-malignant cases in the test set. The ROC analysis was made directly from the estimates of probability of malignancy made by the statistical prediction rule and also from estimates made by radiologist observers after receiving the rule's estimate as an advisory.

Cases were obtained retrospectively at the two clinical sites and were selected to represent malignancies, benign lesions, and "suspicious" cases that were determined subsequently to be "normal." Images taken at two different times were included -- the images first deemed suspicious and the images of the last preceding examination.

The radiologist observers are representative of the referral and community-hospital settings, respectively -- the former being more highly specialized in mammography. The statistical prediction rule, or decision aid, is thus as effective as specialists can make it, but, we think, still suitable for the different case mixes of various screening settings.

The checklist of all diagnostically important perceptual features is an aid to the radiologist in making a complete assessment of image information, so not to be lulled by a premature "satisfaction of search" when a few dominant features appear. Following the checklist, however, may take additional time and the radiologist may choose to use it only for difficult cases. In the envisioned practical computer system, desired cases can be selected for system application in a seamless way, interwoven with cases not selected; with computer-based speech recognition, the microphone usually used for dictation controls the use of the decision aids. Additional motivation for using the decision system, beyond enhancements of accuracy, include the automated report as well as a rich database of diagnostic findings and treatment outcomes on all cases to help assure quality in several ways. Overall, we expect the cost-benefit tradeoff to favor system use.

BODY OF REPORT

The Body of the Report that follows contains a section on each of the main technical tasks accomplished in Year 3 of the project: 1. Case Selection; 2. Checklist Development; 3. Automated Report Writer; 4. Data Entry; and 5. Image-Reading Sessions.

1. Case Selection

As outlined in the original workplan, cases have been qualified and entered into the study from two sources -- Brigham and Women's Hospital and Harvard Pilgrim Health Care. The Human Research Committees of both institutions have approved the study protocol. Cases have been enrolled in 3 categories -- malignant, benign, and "suspicious normal". Tables I and II summarize eligibility criteria and the enrollment statistics of the final case sets.

Table I. Eligibility Criteria and Enrollment Statistics

Category	Definition	Method of Proof	Final Case Sets at	
			BWH	HCHP
Malignant	All types of breast cancer except lobular carcinoma-in-situ	Pathology	107	50
Benign	Focal, nonmalignant processes (i.e., benign tumors)	Pathology	53	51
Suspicious	Patient referred for additional imaging studies or accelerated follow-up and not returned to routine screening pool	Clinical/Imaging (i.e., no change in lesion appearance monitoring)	51	49
			(Total = 211)	(Total = 150)

The further distribution of cases over types of mammographic indication are:

Table II. Distribution of Cases over Types of Mammographic Indication

TYPE	BWH				HPHC			
	Suspicious Normal	Benign	Malignant	Total	Suspicious Normal	Benign	Malignant	Total
Architectural distortion	1	1	10	12	1	0	0	1
Asymmetric density	7	4	3	14	17	1	2	20
Clustered calcifications	5	30	35	20	10	23	17	50
Regional calcifications	3	4	6	13	0	3	0	3
Mass	35	14	53	102	21	24	31	76

Patients selected fit the demographics of the mammography referral (BWH) and screening (HPHC) practices at our two sites. This fit ensures adequate enrollment of minority groups.

For each eligible case, all available original mammographic and ultrasound images at the time of the “target” examination (i.e., when the suspicious focus was identified) were harvested for use. In addition, in order to support development and evaluation of “interval change” features, mammographic images from a “comparison” examination dating approximately 12 months (range 6 to 18 months) before the target examination were also pulled. Patient-identifying information was covered by removable tape and a study number assigned to each case to ensure patient confidentiality.

The quality of images in each case enrolled at BWH was assessed by one of the BWH investigators (T.F.) who rated overall quality on an ordinal scale (1 to 10). Likewise, by an investigator at HPHC (J.M.). In addition, these individuals confirmed

that all needed views were available and confirmed selection of the appropriate “comparison study.” In preparation for training the statistical prediction rule, another of the BWH investigators (J.E.M.) reviewed all the selected images and listed the coordinates of the most suspicious mammographic abnormality. This step ensured that the expert readers rendered feature ratings on the same lesion.

All available clinical mammographic and pathology data were summarized in an electronic relational database (File Maker Pro) to facilitate data extraction for the study.

2. Checklist Development

It remained at the beginning of Year 3, before conducting the feature assessment study at BWH, to convert the master checklist questionnaire into modular form. We created a separate module for each of the five different forms of radiographic presentation of the lesions that occurred in both the BWH and HPHC cases samples: 1) Mass; 2) Not -Definitely-Benign Calcifications; 3) Asymmetric Breast Tissue; 4) Architectural Distortion; and 5) Regional Calcifications. This modular arrangement enabled the reader to proceed efficiently, following just that module or combination of modules that applied to the case at hand. The five modules are attached in Appendix A.

3. Automated Report Writer

The role of the automated report writer is to produce a written English version of the information that the radiologist has entered into the questionnaire. The reports should sound both fluent and natural and they should stay within the guidelines provided by the American College of Radiology.

In the three years of this project, we have successfully built a prototype report generator that takes as input the data from the questionnaire and produces a

standardized report. In order to target the work, we focused on one type of case, those with mass findings. However, the system is easily extended to other types of cases. We produced reports for over five hundred cases in the database.

The efforts over the three years of the project breaks down as follows:

- Year One:
 - Analyze the complexity of the problem and assess the different approaches to text generation and how they apply to this problem.
 - Work along with those creating the questionnaire to ensure that the information necessary for the report will be elicited.
- Year Two:
 - Collect actual reports and compare the information in them with the information in the questionnaire.
 - Analyze the textual variations and compare them with specifications in the BiRads™ document "Breast Imaging Reporting and Data System."
 - Design an architecture for the report writing system.
- Year Three:
 - Implement a prototype of the automated report writer and test it on actual data produced by the system.
 - Provide reports to radiologists for feedback.

The work of the first two years of the project is described in the previous annual reports; we focus here on summarizing the architecture of the system and describing the implementation and testing.

We first summarize the final system and the results.

Generated Reports

The reports are generated in three parts, the introduction, findings and conclusion. The introduction includes not only the heading with the case number and

data, but also a summary of the history, in particular whether the examination is with respect to a previous examination, and information on the overall condition of the breast.

The second paragraph of the report describes the findings. Each item in the questionnaire is incorporated into a sentence. In some cases, multiple items are combined, such as the size and location of the mass. Other items are rendered as complete sentences, such as the presence of microlobulation or other conditions. The conclusion indicates the likelihood that the findings are malignant.

An example of an automatically generated report is shown below. The database input for this paragraph is included in Appendix D. We also include a set of 30 paragraphs selected randomly from the case set in Appendix B, and a set of six paragraphs that are generated from different readings of the same case in Appendix C.

Case #118 2/11/1992

The present examination is compared to a prior mammogram of 5/31/1990. The breast is almost entirely fat. The tissue has a low density.

There is a new 11 mm irregular mass with some evidence of tissue invasion located at the approximate 3 o'clock middle position of the right breast. A small portion of the margin is indistinct due to tissue invasion. About half of the margin is obscured by glandular tissue. About half of the margin is clearly circumscribed. Microlobulation is present. The mass may be an intramammary node.

There is a 85% likelihood that the mass is malignant.

As we describe in more detail in the next section, the paragraph is generated from a set of rules that take into consideration all of the different features and their values in the database that report on masses. The rules can be easily changed to make minor changes in the text of the report.

The process of determining the actual wording is done in three stages, the first two of which are complete:

1. Analyze the wording in reports written by radiologist, which was provided by Brigham and Women's Hospital.
2. Work iteratively with the BBN team, including our domain experts to ensure that the wording accurately expressed the information in the questions and the choice of boundary points is correct, for example if the value on a 1 to 10 scale is 4, the wording might be "a small portion", but if the value is 8, the wording might be "most of the..."
3. Get feedback from radiologists by (1) giving radiologists sample reports and questionnaires and asking them to "grade" them, (2) asking radiologists to write a report after filling out a questionnaire and comparing it to the automatically generated report.

System Architecture

The main goal of the system design was to use the simplest possible technology that would solve the problem in a robust and portable way. Since the database is completely prespecified (that is there will be no new fields or values while the system is in use) and the goal of the resulting paragraphs is clarity and consistency, rather than creativity, we decided to use a simple "direct replacement" grammar approach. There are two advantages to this approach:

- All of the information specific to the domain, such as the order of the different parts of the report and the specific words to be used, are maintained in a declarative set of rules independent of the code that runs to produce the report. This make it both easy to make small modification to the report, such as changes in wording or additions of other information and to move the system to whole new domains, either within mammography or to new areas.
- The system runs very fast, since at each point it only needs to select among a small number of alternatives and the computation required to make the selection is usually just a lookup in the database and comparison of number (e.g., is the value less than four, or between five and seven, etc.).

The major disadvantage is there is a limit in the sophistication of the text one can generate. For example, since there is no link between different parts of the report or even

between different sentences, the wording is often repetitious. For example, the two sentences in the above report "About half of the margin is obscured by glandular tissue. About half of the margin is clearly circumscribed." would be more fluent if combined: "About half of the margin is obscured by glandular tissue and the other half is clearly circumscribed."

We decided to approach the architecture by using the simplest possible mechanisms for the first prototype to understand how far they would go and then incrementally add complexity where it is most needed. Too often, overly complex software is used to solve a simple problem, which adds to both development and maintenance time. We would like to complete a full round of evaluations with radiologists before moving forward on increasing the system's complexity.

The Generation Grammar

The grammar rules contain all of the information on how the report should be organized and what the wording should be in the individual sentences. A rule consists of a nonterminal that will be expanded (called the "left hand side" of the rule), and a set of one or more expansions for that nonterminal (called the "right hand side"). For example, the first rule in the system, shown below, has the nonterminal \$REPORT as its left hand side (nonterminals are preceded by the special symbol \$) and then one right hand side option for expansion.

```
(defrule ($REPORT  
  > $INTRO $FINDINGS $CONCLUSION))1
```

Each nonterminal on the right hand side is a nonterminal on the left hand side somewhere in the grammar. The system recursively expands each of those nonterminals as it processes the paragraph, so for example \$INTRO is expanded into \$CASE \$DATE \$HISTORY \$COMPOSITION, as shown in the rule below, which again has only one alternative.

```
(defrule ($INTRO  
  > $CASE $DATE $HISTORY $COMPOSITION))
```

In some cases, the system needs to insert a value from the database. So in the expansion of \$HISTORY, the system prints the words "The present examination is compared to a prior mammogram of " (words are in quotes) and then gets the actual date from the database. Note that this rule also has a condition, that is, it only prints the sentence if there is in fact a value in the database for the previous date (DATE_P). Otherwise the rule is not expanded.

```
(defrule ($HISTORY  
  > "The present examination is compared to a prior mammogram of "  
  (:VALUE DATE_P) ". "  
  :CONDITION :EXISTS DATE_P))
```

The nonterminal \$COMPOSITION expands to two nonterminals, \$GLANDULAR and \$DENSITY. Each of these has several alternatives, each conditioned on the value in the database.

```
(defrule ($COMPOSITION  
  > $GLANDULAR $DENSITY))
```

¹ To make the example clearer, we have left out text formatting information from the rules shown here. A complete list of the actual rules is in Appendix E.

The conditions in the \$GLANDULAR rule look at the result of the question "Percentage of tissue that is glandular," which is a value between 0 and 100. The rule has four alternatives to choose from, each results in a full sentence being added to the report. Note that if one wanted to change either the range for each choice or the particular wording, one would only have to change this rule.

```
(defrule ($GLANDULAR
  > "The breast is almost entirely fat. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 0 20
  > "The breast is largely fat. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 21 49
  > "The breast is largely fibroglandular. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 50 79
  > "The breast is almost entirely fibroglandular. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 80 100))
```

System Implementation

The report writing prototype is implemented as a stand-alone system that generates reports "off line," that is, the information in the database was saved to an ascii file that was then input to the report writer, which produced all of the reports in batch mode. The prototype is written in Lisp and runs on a Sparc Ultra, but it could be easily ported to a PC using a platform-independent language such as Java.

We tested the system by running it on 531 cases, which the system processed in under 10 seconds per case. Since all of the domain-specific information is encoded in the grammar, the same core system will generate reports of any kind, as long as the form of the input is similar. This means that the system can easily be extended to other finding types and other types of radiology reports with no changes to the computer code.

Future Directions

We have completed a prototype system capable of producing reports automatically from the database. The next step is to get feedback on the readability of the

reports and whether the wording accurately captures the intentions of the radiologists when they put a particular response in the questionnaire. When they say that the percentage of tissue that is glandular is 45% would they also write that "The breast is largely fibroglandular?" Also, what is the most effective way of showing the experts the rules so that they can easily make the appropriate changes to wording? We have experimented with producing a text version of the expansion of all of the rules (see Appendix F). Is this easier to understand than the raw rule format?

Another important area is the integration of the prototype with the full system, which would allow the reports to be produced directly after the questionnaire is filled out. This would require porting to the PC platform and integrating more tightly with the actual format of the database being used.

Finally, we need to reassess whether this most simple form of text generation technology is actually powerful enough for the application, and if not, we need to determine which kinds of extensions will provide the most improvement.

4. Data Entry

In Year 2 we constructed a data-entry program to permit radiologist readers to enter their responses to the checklist/questionnaire by speaking them. In Year 3, we determined that even Release 2 of the Phonetic Engine 500 speech-recognition system was not adequate for use in the clinical setting, primarily because the recognition of digits -- our primary data -- was not sufficiently reliable. In the process, the program was modified to accept keyboard/mouse entry instead of voice. It was further modified to permit research assistants to enter orally data that had been recorded on the questionnaires in written form, to give us experience with the speech-recognition system

without impacting radiologists. A further program was written to permit research assistants to record radiologists' responses on a lap-top computer, for use with the enhanced reading at HPHC. The program calculated the statistical estimate prediction rule's estimate of probability of malignancy on each case for immediate feedback to the radiologist.

5. Image-Reading Sessions

BWH Readings

Five radiologists at BWH read 200 cases, assigning a value to each of 66 perceptual features for each case. These data were the basis for two statistical prediction rules developed by a stepwise logistic-regression procedure -- one for masses and one for clustered calcifications. The features selected for each prediction rule are shown in Table III.

Table III. Features Selected for Prediction Rules

Rule	Features
For Masses	Shape of mass
	Percent of margin that is clearly circumscribed
	Size of mass: computed ratio (maximum size/minimum size)
	Density of mass relative to surrounding glandular tissue
	Patient age
	Size of mass: computed change (current study - prior study)
	Presence of related architectural distortion
	Presence of worrisome calcifications
For Calcifications	Presence of related architectural distortion
	Patient age
	Percent of tissue that is glandular
	Change in size of focal distribution over time: computed ((current study - prior study)/years between studies)
	Degree to which the distribution can be characterized as segmental
	Degree to which the distribution can be characterized as linear
	Degree to which elements can be characterized as fine linear
	Degree to which elements can be characterized as pleomorphic

The performances of the pooled readers and the two statistical prediction rules are given in Table IV in terms of the ROC accuracy index A_z (which varies from 0.5 to 1.0).

Table IV. Performances (A_z) of Readers (Pooled) and Statistical Prediction Rules

		Malignant vs. Benign-Biopsy	All Cases	Malignant vs. Suspicious Normal
MASSES (N ~ 510)	Readers	.875	.936	.962
	Statistical Prediction Rule	.881	.943	.966
	Readers		.725	
CLUSTERED CALCIFI CATIONS (N ~ 350)				
	Statistical Prediction Rule		.739	

As an ancillary analysis, we measured the performances on the cases with a mass for perceptual features taken from ultrasound imagery, a modality usually used only to determine if masses are cysts. As shown in Table V with comparative figures, the novel result is that a statistical prediction rule for the malignant/nonmalignant distinction that is based only on ultrasound features performs very well as a diagnostic tool for that distinction.

Table V. Performances of Ultrasound Features A_z

Readers	.939
Statistical Prediction Rule for cases with mammography features	.981
SPR for cases with ultrasound features	.925
SPR for cases with both types of feature	.983

HPHC Baseline Readings

Baseline (unaided) readings of 150 cases were made by five radiologists at HPHC, in anticipation of aided readings in Year 4. The individual performances are given in Table VI in terms of three measures: A_z , true-positive proportion at false-positive proportion = 0.5, and positive predictive value.

Table VI. Three Measures of HPHC Baseline Reading Performance

Reader	A_z	TPP@FPP = .50	PPV
1	.85	.90	.47
2	.91	.97	.49
3	.84	.89	.47
4	.82	.88	.47
5	.84	.93	.48
Mean	.85	.91	.48

With A_z based on pooled (vs. average data), the Table VII gives a comparison of HPHC performance on (1) all cases, (2) masses alone, and (3) clustered calcifications only. The same comparison is given for BWH performances.

Table VII. Pooled Values of A_z for HPHC and BWH Readers

	All Cases	Masses	Calcifications
HPHC	.83	.85	.78
BWH	.86	.94	.73

The written instructions for the HPHC baseline readings are given in Appendix G.

Enhanced Reading Study at HPHC

All of the main preparations for conducting the enhanced reading study at HPHC have been completed. We have conducted an initial briefing session for the readers as a group to go over the general procedure for the reading sessions. This group session also included training on several of the calcification features that we have learned in prior

studies need some close explanation and illustration. The training images and feature data were taken from cases employed, and readings generated, in the BWH study. We are presently involved in physically assembling and hanging the 50-case set for the first of three enhanced reading sessions and are scheduling the readers for sessions beginning in early January. We anticipate completing data collection and analyses by the end of March.

CONCLUSIONS

The tasks scheduled for Year 3 were accomplished, including final assembly of the BWH and HPHC case sets; readings by BWH readers for training five modular versions of the statistical prediction rule; construction of an initial, flexible, extensible version of an automated report writer; computer programming for non-voice data entry; baseline readings by HPHC readers; and initial training for enhanced readings by HPHC readers.

The project is proceeding successfully. A proposal to the U.S. Army Medical Research and Materiel Command -- to install the mammography decision-aiding system on the World Wide Web -- was invited by the Army and submitted 17 November 1997.

SCHEDULE

The enhanced readings by HPHC radiologists are to be conducted in January to March, 1998, and the data should be analyzed within the next month. A statistical prediction rule based on a neural-network approach will be constructed and compared with the existing logistic-regression version. Focus groups of referring physicians, oncologists, and surgeons will be conducted for preliminary evaluation of the automated report writer. The final report of the project is expected to be prepared on schedule.

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Appendix A: Five Modular Responses Forms

Reader No. _____

Case No. _____

Finding No. _____

Response Form--X-Ray Mammography

Overview of Breast Images

- Percentage of Tissue that is Glandular

Current _____ %

OV02

- Identify the finding

FNDG1

- ☐ Mass
- ☐ Not-definitely-benign calcifications
- ☐ Asymmetric Breast Tissue
- ☐ Architectural Distortion
- ☐ Regional Calcifications

Module I

Reader No. _____

Case No. _____

Finding No. _____

Mass (MM)

Relationship to Prior Study

- This mass finding is:

MM20

- ☐ new
- ☐ not significantly changed
- ☐ significantly changed

***If significantly changed, also rate the prior images where requested.
Otherwise, rate only the current images.***

- Density of mass relative to surrounding glandular tissue

Current	0	1	2	3	4	5	6	7	8	9	10	MM04
	mass density much lower			isodense				mass density much higher				

- Confidence about the presence of fat within the mass

Current	0	1	2	3	4	5	6	7	8	9	10	MM05
	definitely NONE present							definitely some present				

- Size of mass

Current : Largest diameter (in either CC or oblique view) _____ mm MM06

Current : Smallest diameter (in either CC or oblique view) _____ mm MM07

Prior: Largest diameter (in either CC or oblique view) _____ mm MM06

Prior: Smallest diameter (in either CC or oblique view) _____ mm MM07

Mass (MM) - cont.

- Shape of mass

Current	0	1	2	3	4	5	6	7	8	9	10	MM10
	round/oval					lobular					irregular	
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Percentage of the margin that is clearly circumscribed

Current	_____ %	MM13A
Prior	_____ %	

- Confidence that at least a small portion of the margin is spiculated

Current	0	1	2	3	4	5	6	7	8	9	10	MM12
	definitely NOT spiculated										definitely spiculated	

- Confidence that the mass is an intramammary node

Current	0	1	2	3	4	5	6	7	8	9	10	MM16
	definitely NOT an intramammary node										definitely an intramammary node	

- Confidence regarding the presence of related architectural distortion

Current	0	1	2	3	4	5	6	7	8	9	10	MM17
	definitely NOT present										definitely present	

- Confidence regarding the presence of worrisome calcifications within the mass

Current	0	1	2	3	4	5	6	7	8	9	10	MM18
	definitely NOT present										definitely present	

Mass (MM) - cont.

.....

Initial Overall Diagnostic Judgment

● **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

MMRA1

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Computed Probability of Malignancy: _____

.....

Final Overall Diagnostic Judgment

● **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

MMRA2

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Module II

Reader No. _____

Case No. _____

Finding No. _____

Calcifications (Not-Definitely-Benign) (NC)

Relationship to Prior Study

- This not-definitely-benign calcifications finding is:

NC21

- ☐ new
- ☐ not significantly changed
- ☐ significantly changed

***If significantly changed, also rate prior images where requested.
Otherwise, rate only the current images.***

Element Characteristics

- Size of largest individual element (best visual estimate)

Current

☐

less than 0.5 mm

☐

0.5 mm to 1.0 mm

☐

more than 1.0 mm

NC05

- Variability of size of elements

Current

0

1

2

3

4

5

6

7

8

9

10

NC06

low variability
of size

high variability
of size

Calcifications (Not-Definitely-Benign)(NC) - cont.

- Degree to which the elements can be characterized as fine linear

Current	0	1	2	3	4	5	6	7	8	9	10	NC07
	definitely NONE of the elements are fine linear									at least one or two elements definitely are, or several probably are, fine linear		
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Degree to which the elements can be characterized as branching

Current	0	1	2	3	4	5	6	7	8	9	10	NC08
	definitely NONE of the elements are branching									at least one or two elements definitely are, or several probably are, branching		
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Degree to which the elements can be characterized as pleomorphic (heterogeneous)

Current	0	1	2	3	4	5	6	7	8	9	10	NC09
	definitely NONE of the elements are pleomorphic (heterogeneous)									at least one or two elements definitely are, or several probably are, pleomorphic (heterogeneous)		

Prior 0 1 2 3 4 5 6 7 8 9 10 ● Degree
the elements can be characterized as punctate

Current	0	1	2	3	4	5	6	7	8	9	10	NC11	definitely
	definitely NONE of the elements are punctate									at least one or two elements definitely are, or several probably are, punctate			

Distribution Characteristics

- Number of elements

Current	○	○	○	NC13
	less than 5	5 to 10	more than 10	

Calcifications (Not-Definitely-Benign)(NC) - cont.

- Size of the focal distribution

Largest dimension in CC view

Current _____ mm

NC14

Prior _____ mm

NC14

- Degree to which the distribution can be characterized as linear

Current	0	1	2	3	4	5	6	7	8	9	10	NC17
	definitely NOT linear										definitely linear	
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Degree to which the distribution can be characterized as segmental

Current	0	1	2	3	4	5	6	7	8	9	10	NC18
	definitely NOT segmental										definitely segmental	
Prior	0	1	2	3	4	5	6	7	8	9	10	

Relationship to Other Aspects of This Study

- Confidence regarding presence of related architectural distortion

Current	0	1	2	3	4	5	6	7	8	9	10	NC19
	definitely NOT present										definitely present	

- Confidence regarding presence of related mass or asymmetric breast tissue

Current	0	1	2	3	4	5	6	7	8	9	10	NC20
	definitely NOT present										definitely present	

Calcifications (Not-Definitely-Benign)(NC) - cont.

.....

Initial Overall Diagnostic Judgment

- **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

NCRA1

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Computed Probability of Malignancy: _____

.....

Final Overall Diagnostic Judgment

- **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

NCRA2

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Module III

Reader No. _____

Case No. _____

Finding No. _____

Asymmetric Breast Tissue (AT)

Relationship to Prior Study

- This asymmetric tissue finding is:

AT10

- ☐ new
- ☐ not significantly changed
- ☐ significantly changed

***If significantly changed, also rate the prior images where requested.
Otherwise, rate only the current images.***

- Size of distribution of asymmetric breast tissue

	Current	Prior	
Largest diameter in CC view	_____ mm	_____	AT05
Largest diameter in oblique view	_____ mm	_____	AT06

- Confidence regarding the presence of worrisome calcifications within the asymmetric breast tissue

Current	0	1	2	3	4	5	6	7	8	9	10	AT07
	definitely NOT present										definitely present	
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Confidence regarding presence of related architectural distortion

Current	0	1	2	3	4	5	6	7	8	9	10	AT09
	definitely NOT present										definitely present	
Prior	0	1	2	3	4	5	6	7	8	9	10	

Asymmetric Breast Tissue (AT) - cont.

.....

Overall Diagnostic Judgment

- **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

ATRA

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Module IV

Reader No. _____

Case No. _____

Finding No. _____

Architectural Distortion (AD)

Relationship to Prior Study

- This architectural distortion finding is:

AD11

- ☐ new
- ☐ not significantly changed
- ☐ significantly changed

***If significantly changed, also rate the prior images where requested.
Otherwise, rate only the current images.***

- Confidence that the architectural distortion is related to prior surgery

Current	0	1	2	3	4	5	6	7	8	9	10	AD06
	definitely NOT related to prior surgery										definitely related to prior surgery	
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Confidence regarding the presence of related worrisome calcifications

Current	0	1	2	3	4	5	6	7	8	9	10	AD07
	definitely NOT present										definitely present	
Prior	0	1	2	3	4	5	6	7	8	9	10	

Architectural Distortion (AD) - cont.

- Confidence regarding the presence of a related mass

Current	0	1	2	3	4	5	6	7	8	9	10	AD09
	definitely NOT present									definitely present		
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Confidence regarding the presence of related asymmetric breast tissue

Current	0	1	2	3	4	5	6	7	8	9	10	AD10
	definitely NOT present									definitely present		
Prior	0	1	2	3	4	5	6	7	8	9	10	

.....

Overall Diagnostic Judgment

- **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

ADRA

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Module V

Reader No. _____

Case No. _____

Finding No. _____

Regional Calcifications (Not-Definitely-Benign) (RC)

Relationship to Prior Study

- This regional calcifications finding is:

RC21

- ☐ new
- ☐ not significantly changed
- ☐ significantly changed

***If significantly changed, also rate the prior images where requested.
Otherwise, rate only the current images.***

Element Characteristics

- Size of largest individual element (best visual estimate)

Current ☐ ☐ ☐

less than 0.5 mm 0.5 mm to 1.0 mm more than 1.0 mm

RC05

- Variability of size of elements

Current 0 1 2 3 4 5 6 7 8 9 10

low variability of size high variability of size

RC06

- Degree to which the elements can be characterized as fine linear

Current 0 1 2 3 4 5 6 7 8 9 10

definitely NONE of the elements are fine linear at least one or two elements definitely are, or several probably are, fine linear

Prior 0 1 2 3 4 5 6 7 8 9 10

RC07

Calcifications (Not-Definitely-Benign) (RC) - cont.

- Degree to which the elements can be characterized as branching

Current	0	1	2	3	4	5	6	7	8	9	10	RC08
	definitely NONE of the elements are branching									at least one or two elements definitely are, or several probably are, branching		
Prior	0	1	2	3	4	5	6	7	8	9	10	

- Degree to which the elements can be characterized as pleomorphic (heterogeneous)

Current	0	1	2	3	4	5	6	7	8	9	10	RC09
	definitely NONE of the elements are pleomorphic (heterogeneous)									at least one or two elements definitely are, or several probably are pleomorphic (heterogeneous)		

Prior	0	1	2	3	4	5	6	7	8	9	10	●
--------------	---	---	---	---	---	---	---	---	---	---	----	---

to which the elements can be characterized as punctate

Current	0	1	2	3	4	5	6	7	8	9	10	RC11
NONE of the	at least one or two elements are punctate									elements definitely are, or several probably are punctate		

Relationship to Other Aspects of This Study

- Confidence regarding presence of related architectural distortion

Current	0	1	2	3	4	5	6	7	8	9	10	RC19
	definitely NOT present										definitely present	

- Confidence regarding presence of related mass or asymmetric breast tissue

Current	0	1	2	3	4	5	6	7	8	9	10	RC20
	definitely NOT present										definitely present	

Regional Calcifications (Not-Definitely-Benign) (RC) - cont.

.....

Overall Diagnostic Judgment

- **Benign vs. Malignant**

Rate the likelihood (as the number of chances in 100) that the finding is indicative of malignancy:

Rating (0 to 100) _____

where: 0 = certainly benign or normal

100 = certainly malignant

.....

Appendix B: Sample Reports of Automated Report Writer

The following are a set of 30 cases selected from random from the database of 531 cases.

Case #118 2/11/1992

The present examination is compared to a prior mammogram of 5/31/1990. The breast is almost entirely fat. The tissue has a low density.

There is a new 11 mm irregular mass with some evidence of tissue invasion located at the approximate 3 o'clock middle position of the right breast. A small portion of the margin is indistinct due to tissue invasion. About half of the margin is obscured by glandular tissue. About half of the margin is clearly circumscribed. Microlobulation is present. The mass may be an intramammary node.

There is a 85% likelihood that the mass is malignant.

Case #136_1 12/2/1993

The present examination is compared to a prior mammogram of 12/31/1992. The breast is largely glandular. The tissue is moderately dense.

There is a new 25 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock posterior position of the left breast. About half of the margin is spiculated. About half of the margin is indistinct due to tissue invasion. Microlobulation is present. Architectural distortions are evident. Worrisome and benign calcifications are present.

There is a 100% likelihood that the mass is malignant.

Case #143L 8/27/1990

The present examination is compared to a prior mammogram of 5/11/1989. The breast is almost entirely fat. The tissue has a low density.

There is a 6 mm round/oval mass located at the approximate 9 o'clock middle position of the left breast. It has not changed significantly since the last exam. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. The mass may be a skin lesion. The mass may be an intramammary node.

There is a 0% likelihood that the mass is malignant.

Case #145 3/13/1992

The present examination is compared to a prior mammogram of 6/25/1990. The breast is largely glandular. The tissue is very dense.

There is a new 7 mm round/oval mass with some evidence of spiculation and tissue invasion located at the approximate 9 o'clock middle position of the left breast. A small portion of the margin is indistinct due to tissue invasion. A large portion of the margin is obscured by glandular tissue. Some of the margin is clearly circumscribed.

An ultrasound was performed. The mass appears irregular with solid contents. The mass wall is indistinct. The posterior wall of the mass displays shadowing.

There is a 75% likelihood that the mass is malignant.

Case #151 7/6/1994

The present examination is compared to a prior mammogram of 7/30/1993. The breast is almost entirely fat. The tissue has a low density.

There is a 13 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 6 o'clock middle position of the right breast. It has not changed significantly since the last exam. A small portion of the margin is indistinct due to tissue invasion. A large portion of the margin is obscured by glandular tissue. A small portion of the margin is clearly circumscribed. Microlobulation is present. The mass may be an intramammary node.

There is a 40% likelihood that the mass is malignant.

Case #164 10/30/1992

The present examination is compared to a prior mammogram of 4/19/1990. The breast is almost entirely fat. The tissue has a low density.

There is a new 10 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 11 o'clock middle position of the right breast. About half of the margin is spiculated. About half of the margin is indistinct due to tissue invasion. Microlobulation is present.

There is a 100% likelihood that the mass is malignant.

Case #189 8/11/1994

The present examination is compared to a prior mammogram of 12/8/1992. The breast is almost entirely glandular. The tissue is moderately dense.

There is a new 9 mm round/oval group of similar masses located at the approximate 12 o'clock middle position of the left breast. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. Microlobulation is present. The mass appears to be an intramammary node.

There is a 5% likelihood that the mass is malignant.

Case #201 1/6/1995

The present examination is compared to a prior mammogram of 7/16/1993. The breast is almost entirely fat. The tissue has a low density.

There is a new 13 mm lobular mass with some evidence of tissue invasion located at the approximate 1 o'clock middle position of the right breast. A large portion of the margin is obscured by glandular tissue. Some of the margin is clearly circumscribed. The mass may be an intramammary node.

An ultrasound was performed. The mass appears ellipsoid with solid contents. The mass wall is well-circumscribed. The posterior wall of the mass is iso-echoic.

There is a 50% likelihood that the mass is malignant.

Case #223_1 12/16/1992

The present examination is compared to a prior mammogram of 7/19/1990. The breast is largely glandular. The tissue is moderately dense.

There is a new 7 mm irregular group of similar masses with some evidence of spiculation and tissue invasion located in the left breast. A large portion of the margin is spiculated. A small portion of the margin is indistinct due to tissue invasion. A small portion of the margin is obscured by glandular tissue. Microlobulation is present. Architectural distortions are evident.

There is a 99% likelihood that the mass is malignant.

Case #230 10/11/1991

The present examination is compared to a prior mammogram of 8/14/1990. The breast is almost entirely fat. The tissue has a low density.

There is a 9 mm round/oval group of similar masses located at the approximate 10 o'clock posterior position of the right breast. It has not changed significantly since the last exam. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. The mass is definitely an intramammary node.

There is a 0% likelihood that the mass is malignant.

Case #254 1/5/1994

The present examination is compared to a prior mammogram of 12/17/1992. The breast is almost entirely fat. The tissue has a low density.

There is a 11 mm irregular mass with some evidence of spiculation and tissue invasion anterior of the right breast. It has changed significantly since the last exam. About half of the margin is spiculated. This is a significant increase from prior

examinations. About half of the margin is indistinct due to tissue invasion. This is a significant increase from prior examinations. This is a decrease from prior examinations.

There is a 100% likelihood that the mass is malignant.

Case #272 11/30/1992

The present examination is compared to a prior mammogram of 11/19/1991. The breast is almost entirely fat. The tissue has a low density.

There is a 15 mm round/oval mass located at the approximate 7 o'clock middle position of the right breast. It has not changed significantly since the last exam. A small portion of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. The mass may be an intramammary node.

There is a 5% likelihood that the mass is malignant.

Case #284 9/9/1992

The present examination is compared to a prior mammogram of 10/31/1990. The breast is largely fat. The tissue is moderately dense.

There is a new 10 mm lobular mass located at the approximate 7 o'clock anterior position of the left breast. A small portion of the margin is indistinct due to tissue invasion. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. The mass appears to be a skin lesion.

There is a 50% likelihood that the mass is malignant.

Case #293 5/7/1991

The present examination is compared to a prior mammogram of 10/2/1990. The breast is almost entirely glandular. The tissue is very dense.

There is a 30 mm round/oval group of similar masses located at the approximate 6 o'clock middle position of the left breast. It has not changed significantly since the last exam. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed.

An ultrasound was performed. The mass appears ellipsoid with cystic contents. The mass wall is well-circumscribed. The posterior wall of the mass displays enhancement.

There is a 0% likelihood that the mass is malignant.

Case #307 4/15/1992

The present examination is compared to a prior mammogram of 4/13/1990. The breast is largely glandular. The tissue is very dense.

There is a new 6 mm round/oval mass located in the right breast. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. The mass is definitely an intramammary node.

There is a 0% likelihood that the mass is malignant.

Case #328 5/1/1995

The present examination is compared to a prior mammogram of 5/3/1994. The breast is almost entirely fat. The tissue is moderately dense.

There is a 11 mm lobular group of similar masses located at the approximate 3 o'clock posterior position of the left breast. It has changed significantly since the last exam. A small portion of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. There is extensive microlobulation present. The mass may be a skin lesion. The mass appears to be an intramammary node.

An ultrasound was performed. The mass appears ellipsoid with solid contents. The mass wall is well-circumscribed. The posterior wall of the mass displays enhancement.

There is a 10% likelihood that the mass is malignant.

Case #350 5/9/1995

The present examination is compared to a prior mammogram of 5/25/1993. The breast is largely fat. The tissue is moderately dense.

There is a 12 mm lobular mass with some evidence of tissue invasion located at the approximate 3 o'clock posterior position of the left breast. It has not changed significantly since the last exam. A large portion of the margin is indistinct due to tissue invasion. About half of the margin is obscured by glandular tissue. Microlobulation is present.

There is a 5% likelihood that the mass is malignant.

Case #357 12/9/1993

The present examination is compared to a prior mammogram of 9/17/1992. The breast is almost entirely fat. The tissue has a low density.

There is a 15 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 4 o'clock posterior position of the left breast. It has changed significantly since the last exam. A large portion of the margin is spiculated. Some of the margin is indistinct due to tissue invasion.

There is a 100% likelihood that the mass is malignant.

Case #380 8/10/1994

The present examination is compared to a prior mammogram of 6/17/1993. The breast is largely glandular. The tissue is moderately dense.

There is a new 10 mm irregular mass with some evidence of spiculation and tissue invasion located in the right breast. Some of the margin is spiculated. A large portion of the margin is indistinct due to tissue invasion. Microlobulation is present.

An ultrasound was performed. The mass appears irregular with solid contents. The mass wall is indistinct. The posterior wall of the mass displays shadowing.

There is a 100% likelihood that the mass is malignant.

Case #393 8/26/1994

The present examination is compared to a prior mammogram of 12/9/1992. The breast is almost entirely glandular. The tissue is very dense.

There is a new 15 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 12 o'clock posterior position of the right breast. Some of the margin is indistinct due to tissue invasion. A large portion of the margin is obscured by glandular tissue. A small portion of the margin is clearly circumscribed. Microlobulation is present. Architectural distortions are evident. Worrisome calcifications are present.

An ultrasound was performed. The mass appears irregular with solid contents. The mass wall is irregular. The posterior wall of the mass displays shadowing.

There is a 100% likelihood that the mass is malignant.

Case #398 8/16/1995

The present examination is compared to a prior mammogram of 8/25/1994. The breast is largely glandular. The tissue is very dense.

There is a new 7 mm lobular mass with some evidence of tissue invasion located at the approximate 2 o'clock position of the left breast. A small portion of the margin is indistinct due to tissue invasion. A large portion of the margin is obscured by glandular tissue. A small portion of the margin is clearly circumscribed. The mass may be an intramammary node.

An ultrasound was performed. The mass appears ellipsoid with solid contents. The mass wall is well-circumscribed. The posterior wall of the mass displays enhancement.

There is a 25% likelihood that the mass is malignant.

Case #412 6/19/1991

The present examination is compared to a prior mammogram of 6/11/1990. The breast is largely fat. The tissue is moderately dense.

There is a 17 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 3 o'clock anterior position of the right breast. It has not changed significantly since the last exam. About half of the margin is spiculated. Some of the margin is indistinct due to tissue invasion. Some of the margin is obscured by glandular tissue. Microlobulation is present. Architectural distortions are evident.

There is a 60% likelihood that the mass is malignant.

Case #421 11/21/1994

The present examination is compared to a prior mammogram of 12/22/1993. The breast is largely glandular. The tissue is moderately dense.

There is a new 21 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 8 o'clock position of the right breast. A small portion of the margin is spiculated. About half of the margin is indistinct due to tissue invasion. About half of the margin is obscured by glandular tissue. Microlobulation is present. Architectural distortions are evident.

An ultrasound was performed. The mass appears irregular with solid contents. The mass wall is irregular. The posterior wall of the mass displays shadowing.

There is a 100% likelihood that the mass is malignant.

Case #441 9/29/1992

The present examination is compared to a prior mammogram of 7/9/1991. The breast is largely fat. The tissue is very dense.

There is a 7 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 1 o'clock posterior position of the right breast. It has changed significantly since the last exam. A large portion of the margin is spiculated. Some of the margin is indistinct due to tissue invasion. There is extensive microlobulation present. Architectural distortions are evident.

There is a 99% likelihood that the mass is malignant.

Case #445 9/15/1993

The present examination is compared to a prior mammogram of 3/19/1993. The breast is almost entirely fat. The tissue has a low density.

There is a 11 mm round/oval group of similar masses located at the approximate 8 o'clock middle position of the right breast. It has changed significantly since the last exam. A small portion of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed.

There is a 5% likelihood that the mass is malignant.

Case #461 9/3/1992

The present examination is compared to a prior mammogram of 9/23/1991. The breast is largely glandular. The tissue is moderately dense.

There is a new 25 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 4 o'clock posterior position of the left breast. Some of the margin is indistinct due to tissue invasion. Microlobulation is present. Architectural distortions are evident. Worrisome calcifications are present.

There is a 100% likelihood that the mass is malignant.

Case #467 2/10/1995

The present examination is compared to a prior mammogram of 10/14/1992. The breast is largely fat. The tissue is moderately dense.

There is a new 15 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 9 o'clock middle position of the right breast. A large portion of the margin is indistinct due to tissue invasion. Some of the margin is clearly circumscribed. Architectural distortions are evident. Worrisome calcifications are present.

There is a 100% likelihood that the mass is malignant.

Case #479 3/24/1994

The present examination is compared to a prior mammogram of 3/23/1993. The breast is largely glandular. The tissue is moderately dense.

There is a 9 mm lobular mass with some evidence of tissue invasion located at the approximate 9 o'clock middle position of the left breast. It has changed significantly since the last exam. A large portion of the margin is obscured by glandular tissue. About half of the margin is clearly circumscribed. The mass may be a skin lesion. The mass may be an intramammary node.

An ultrasound was performed. The mass appears ellipsoid with solid contents. The mass wall is well-circumscribed. The posterior wall of the mass is iso-echoic.

There is a 10% likelihood that the mass is malignant.

Case #492 4/15/1992

The present examination is compared to a prior mammogram of 2/27/1990. The breast is almost entirely fat. The tissue has a low density.

There is a new 8 mm round/oval mass located at the approximate 8 o'clock middle position of the right breast. A small portion of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed.

There is a 2% likelihood that the mass is malignant.

Case #496 6/18/1992

The present examination is compared to a prior mammogram of 11/15/1990. The breast is almost entirely fat. The tissue has a low density.

There is a 6 mm lobular mass with some evidence of spiculation and tissue invasion located at the approximate 12 o'clock position of the right breast. It has changed significantly since the last exam. Some of the margin is obscured by glandular tissue. A large portion of the margin is clearly circumscribed. Microlobulation is present.

An ultrasound was performed. The mass appears irregular with solid contents. The mass wall is indistinct. The posterior wall of the mass is iso-echoic.

There is a 15% likelihood that the mass is malignant.

Appendix C: Case Descriptions

The following six reports are generated from the same case read by six different radiologists. Note that while their readings (and the reports generated from them) are largely similar, there are some differences.

Case #106 11/16/1993

The present examination is compared to a prior mammogram of 1/13/1992. The breast is largely glandular. The tissue is moderately dense.

There is a 7 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock middle position of the left breast. It has changed significantly since the last exam. Some of the margin is spiculated. This is a decrease from prior examinations. About half of the margin is indistinct due to tissue invasion. This is a significant increase from prior examinations. Some of the margin is obscured by glandular tissue. Architectural distortions are evident.

There is a 90% likelihood that the mass is malignant.

Case #106 11/16/1993

The present examination is compared to a prior mammogram of 1/13/1992. The breast is largely fat. The tissue is moderately dense.

There is a new 7 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock middle position of the left breast. About half of the margin is spiculated. Some of the margin is indistinct due to tissue invasion. Some of the margin is obscured by glandular tissue. There is extensive microlobulation present. The mass may be a skin lesion. The mass may be an intramammary node. Architectural distortions are evident.

There is a 75% likelihood that the mass is malignant.

Case #106 11/16/1993

The present examination is compared to a prior mammogram of 1/13/1992. The breast is largely glandular. The tissue is moderately dense.

There is a new 5 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock middle position of the left breast. About half of the margin is spiculated. About half of the margin is indistinct due to tissue invasion. Microlobulation is present.

There is a 100% likelihood that the mass is malignant.

Case #106 11/16/1993

The present examination is compared to a prior mammogram of 1/13/1992. The breast is largely glandular. The tissue has a low density.

There is a 8 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock middle position of the left breast. It has changed significantly since the last exam. About half of the margin is spiculated. This is a significant increase from prior examinations. Some of the margin is indistinct due to tissue invasion. This is a significant increase from prior examinations. Some of the margin is obscured by glandular tissue. Microlobulation is present. Architectural distortions are evident.

There is a 98% likelihood that the mass is malignant.

Case #106 11/16/1993

The present examination is compared to a prior mammogram of 1/13/1992. The breast is largely glandular. The tissue is moderately dense.

There is a 7 mm irregular mass with some evidence of spiculation and tissue invasion located at the approximate 2 o'clock middle position of the left breast. It has not changed significantly since the last exam. A large portion of the margin is spiculated. Some of the margin is indistinct due to tissue invasion. A small portion of the margin is obscured by glandular tissue. There is extensive microlobulation present. Architectural distortions are evident.

There is a 95% likelihood that the mass is malignant.

Appendix D: Sample Case As Listed in Database

The following is an example of the format of the database which is input to the report generator. Each item is a pair with a keyword, such as CASE, RDR (reader), or the number of an item in the questionnaire, followed by a value, such as the case number, reader's initials, or the value the radiologist entered on the questionnaire for that item. Note that each item can have a current reading (_C) and a previous reading (_P), and that there can be many different findings. The case shown here is fairly short, since there is only one finding and it is new, so most items only have a current but no previous reading.

CASE 118,
RDR PD,
DOB 5/1/14,
TRUTH 1,
PATH M,
DATE_C 2/11/1992,
DATE_P 5/31/1990,
INT_CP 1.7013698630137,
AGE_C 77.8356164383562,
AGE_P 76.1342465753425,
OV02_C 20,
OV02_P 30,
OV03_C 2,
OV03_P 3,
FINDING mm,
MM01A 1,
MM01_C 10,
MM02_C 1,
MM04_C 7,
MM05_C 1,
MM06_C 9,
MM07_C 6,
MM08_C 11,
MM09_C 6,
MM10_C 9,
MM11_C 8,
MM12_C 2,
MM13A_C 40,
MM13B_C 50,
MM13C_C 10,
MM13D_C 0,
MM14_C 5,
MM15_C 0,
MM16_C 1,
MM17_C 1,
MM18_C 0,
MM19_C 0,
MMUL 0,
MMRA 85,
FNDGN 0,
OV02_D -10,
OV02_R -5.87761674718197,
OV03_D -1,
OV03_R -.587761674718196

Appendix E: Generation Rules for Automated Reports

```
(defrule ($REPORT
  > $INTRO $BLANKLINE $FINDINGS $BLANKLINE $CONCLUSION
  $BLANKLINE))

(defrule ($INTRO
  > $CASE $TAB $DATE $BLANKLINE $HISTORY $COMPOSITION))

(defrule ($CASE
  > "Case #" (:VALUE case)
  :CONDITION :EXISTS CASE))

(defrule ($DATE
  > (:VALUE DATE_C)))

(defrule ($HISTORY
  > "The present examination is compared to a prior mammogram of "
  (:VALUE DATE_P) ". "
  :CONDITION :EXISTS DATE_P))

(defrule ($COMPOSITION
  > $GLANDULAR $DENSITY))

(defrule ($GLANDULAR
  > "The breast is almost entirely fat. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 0 20
  > "The breast is largely fat. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 21 49
  > "The breast is largely fibroglandular. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 50 79
  > "The breast is almost entirely fibroglandular. "
  :CONDITION :BETWEEN (:VALUE OV02_C) 80 100))

(defrule ($DENSITY
  > "The fibroglandular tissue has a low density. "
  :CONDITION :BETWEEN (:VALUE OV03_C) 0 3
  > "The fibroglandular tissue is moderately dense. "
  :CONDITION :BETWEEN (:VALUE OV03_C) 4 7
  > "The fibroglandular tissue is very dense. "
  :CONDITION :BETWEEN (:VALUE OV03_C) 8 10))

(defrule ($FINDINGS
  > $MASS-FINDINGS
  :CONDITION :EQUAL (:VALUE FINDING) mm))

(defrule ($MASS-FINDINGS
  > $MASS-DESCRIPTION $MASS-ATTRIBUTES $MASS-ULTRASOUND))

(defrule (
  $MASS-DESCRIPTION
  > "There is a " $MASS-NEW $MASS-SIZE $MASS-SHAPE
  $MASS-DISTRIBUTION $MASS-DANGER $MASS-LOCATION $MASS-CHANGE))

(defrule ($MASS-NEW
  > "new "
  :CONDITION :EQUAL (:VALUE MM01A) 1))
```

```

(defrule ($MASS-SIZE
  > (:MAX-VALUE MM06_C MM07_C MM08_C MM09_C) " mm "
  :CONDITION :EXISTS (:MAX-VALUE MM06_C MM07_C MM08_C MM09_C)))

(defrule ($MASS-SHAPE
  > "round/oval "
  :CONDITION :LESS-OR-EQUAL (:VALUE MM10_C) 2
  > "lobular "
  :CONDITION :BETWEEN (:VALUE MM10_C) 3 7
  > "irregular "
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM10_C) 8))

(defrule ($MASS-DISTRIBUTION
  > "mass"
  :CONDITION :EQUAL (:VALUE MM02_C) 1
  > "group of similar masses"
  :CONDITION :EQUAL (:VALUE MM02_C) 2))

(defrule ($MASS-DANGER
  > " with some evidence of spiculation" $MASS-DANGER2
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM12_C) 3
  > " with some evidence of tissue invasion"
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM11_C) 3))

(defrule ($MASS-DANGER2
  > " and tissue invasion"
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM11_C) 3))

(defrule ($MASS-LOCATION
  > $MASS-POSITION $MASS-SIDE ". "
  :CONDITION :BETWEEN (:VALUE MM03A) 1 14
  > $MASS-DEPTH $MASS-SIDE ". "
  :CONDITION :BETWEEN (:VALUE MM03B) 1 3
  > $ALT-MASS-SIDE ". "
  :CONDITION :BETWEEN (:VALUE MM02A) 1 2
  > ". ")

(defrule ($MASS-POSITION
  > " located at the approximate " (:VALUE MM03A)
  " o'clock " $MASS-DEPTH "position"
  :CONDITION :BETWEEN (:VALUE MM03A) 1 12
  > " located at the central " $MASS-DEPTH "position"
  :CONDITION :EQUAL (:VALUE MM03A) 13
  > " located at the axillary tail " $MASS-DEPTH "position"
  :CONDITION :EQUAL (:VALUE MM03A) 14))

(defrule ($MASS-DEPTH
  > "anterior "
  :CONDITION :EQUAL (:VALUE MM03B) 1
  > "middle depth "
  :CONDITION :EQUAL (:VALUE MM03B) 2
  > "posterior "
  :CONDITION :EQUAL (:VALUE MM03B) 3))

(defrule ($MASS-SIDE
  > " of the left breast"
  :CONDITION :EQUAL (:VALUE MM02A) 1

```

```

> " of the right breast"
:CONDITION :EQUAL (:VALUE MM02A) 2))

(defrule ($ALT-MASS-SIDE
  > " located in the left breast"
  :CONDITION :EQUAL (:VALUE MM02A) 1
  > " located in the right breast"
  :CONDITION :EQUAL (:VALUE MM02A) 2))

(defrule ($MASS-ATTRIBUTES
  > $MASS-SPICULATED $MASS-SPICULATED-CHANGE
  $MASS-INVASION $MASS-INVASION-CHANGE
  $MASS-GLANDULAR $MASS-GLANDULAR-CHANGE
  $MASS-CIRCUMSCRIBED $MASS-CIRCUMSCRIBED-CHANGE
  $MASS-MICROLOBULATION $MASS-SKINLESION
  $MASS-INTRAMAMMARY $MASS-EXTRAS))

(defrule ($MASS-INVASION
  > "A small portion of the margin appears to be indistinct"
  " due to tissue invasion. "
  :CONDITION :BETWEEN (:VALUE MM13C_C) 1 19
  > "Some of the margin appears to be indistinct due to :
  "tissue invasion. "
  :CONDITION :BETWEEN (:VALUE MM13C_C) 20 39
  > "About half of the margin appears to be indistinct due to "
  "tissue invasion. "
  :CONDITION :BETWEEN (:VALUE MM13C_C) 40 59
  > "A large portion of the margin appears to be indistinct due to"
  " tissue invasion. "
  :CONDITION :BETWEEN (:VALUE MM13C_C) 60 99
  > "All of the margin appears to be indistinct due to "
  "tissue invasion. "
  :CONDITION :EQUAL (:VALUE MM13C_C) 100))

(defrule ($MASS-INVASION-CHANGE
  > "This is a significant increase from the prior examination. "
  :CONDITION :GREATER-THAN (:VALUE MM13C_D) 0
  > "This is a decrease from the prior examination. "
  :CONDITION :LESS-THAN (:VALUE MM13C_D) 0))

(defrule ($MASS-SPICULATED
  > "A small portion of the margin is spiculated. "
  :CONDITION :BETWEEN (:VALUE MM13D_C) 1 19
  > "Some of the margin is spiculated. "
  :CONDITION :BETWEEN (:VALUE MM13D_C) 20 39
  > "About half of the margin is spiculated. "
  :CONDITION :BETWEEN (:VALUE MM13D_C) 40 59
  > "A large portion of the margin is spiculated. "
  :CONDITION :BETWEEN (:VALUE MM13D_C) 60 99
  > "All of the margin is spiculated. "
  :CONDITION :EQUAL (:VALUE MM13D_C) 100))

(defrule ($MASS-SPICULATED-CHANGE
  > "This is a significant increase from the prior examination. "
  :CONDITION :GREATER-THAN (:VALUE MM13D_D) 0
  > "This is a decrease from the prior examination. "
  :CONDITION :LESS-THAN (:VALUE MM13D_D) 0))

```

```

(defrule ($MASS-CIRCUMSCRIBED
  > "A small portion of the margin is clearly circumscribed. "
  :CONDITION :BETWEEN (:VALUE MM13A_C) 1 19
  > "Some of the margin is clearly circumscribed. "
  :CONDITION :BETWEEN (:VALUE MM13A_C) 20 39
  > "About half of the margin is clearly circumscribed. "
  :CONDITION :BETWEEN (:VALUE MM13A_C) 40 59
  > "A large portion of the margin is clearly circumscribed. "
  :CONDITION :BETWEEN (:VALUE MM13A_C) 60 99
  > "All of the margin is clearly circumscribed. "
  :CONDITION :EQUAL (:VALUE MM13A_C) 100))

(defrule ($MASS-GLANDULAR-CHANGE
  > "This is a significant increase from the prior examination. "
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM13A_D) 30
  > "This is a decrease from the prior examination. "
  :CONDITION :LESS-OR-EQUAL (:VALUE MM13A_D) -30))

(defrule ($MASS-GLANDULAR
  > "A small portion of the margin appears to be"
  "obscured by glandular tissue. "
  :CONDITION :BETWEEN (:VALUE MM13B_C) 1 19
  > "Some of the margin appears to be obscured by "
  "glandular tissue. "
  :CONDITION :BETWEEN (:VALUE MM13B_C) 20 39
  > "About half of the margin appears to be obscured by "
  "glandular tissue. "
  :CONDITION :BETWEEN (:VALUE MM13B_C) 40 59
  > "A large portion of the margin appears to be obscured by "
  "glandular tissue. "
  :CONDITION :BETWEEN (:VALUE MM13B_C) 60 99
  > "All of the margin appears to be obscured by glandular tissue. "
  :CONDITION :EQUAL (:VALUE MM13B_C) 100))

(defrule ($MASS-GLANDULAR-CHANGE
  > "This is a significant increase from the prior examination. "
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM13B_D) 30
  > "This is a decrease from the prior examination. "
  :CONDITION :LESS-OR-EQUAL (:VALUE MM13B_D) -30))

(defrule ($MASS-MICROLOBULATION
  > "Microlobulation is present. "
  :CONDITION :BETWEEN (:VALUE MM14_C) 3 7
  > "There is extensive microlobulation present. "
  :CONDITION :GREATER-OR-EQUAL (:VALUE MM14_C) 8))

(defrule ($MASS-SKINLESION
  > "The mass " $MASS-SKINLESION-CONFIDENCE " a skin lesion. "
  :CONDITION :GREATER-THAN (:VALUE MM15_C) 4))

(defrule ($MASS-SKINLESION-CONFIDENCE
  > "may be"
  :CONDITION :BETWEEN (:VALUE MM15_C) 5 8
  > "appears to be"
  :CONDITION :GREATER-THAN (:VALUE MM15_C) 8))

  (defrule ($MASS-INTRAMAMARY
    > "The mass " $MASS-INTRAMAMARY-CONFIDENCE

```

```

        " an intramamary node. "
:CONDITION :GREATER-THAN (:VALUE MM16_C) 4))

(defrule ($MASS-INTRAMAMARY-CONFIDENCE
  > "may be"
:CONDITION :BETWEEN (:VALUE MM16_C) 5 8
  > "appears to be"
:CONDITION :GREATER-THAN (:VALUE MM16_C) 8))

(defrule ($MASS-EXTRAS
  > "Architectural distortion is evident. " $MASS-WC
:CONDITION :GREATER-OR-EQUAL (:VALUE MM17_C) 5
  > $MASS-WC))

(defrule ($MASS-WC
  > "Worrisome" $MASS-BC " calcifications are present. "
:CONDITION :GREATER-OR-EQUAL (:VALUE MM18_C) 5
  > "Benign calcifications are present. "
:CONDITION :GREATER-OR-EQUAL (:VALUE MM19_C) 5))

(defrule ($MASS-BC
  > " and benign"
:CONDITION :GREATER-OR-EQUAL (:VALUE MM19_C) 5))

(defrule ($MASS-ULTRASOUND
  > $BLANKLINE "An ultrasound was performed. "
  $MASS-US-SHAPE-CONTENTS $MASS-US-APPEARANCE
  $MASS-US-RESPONSE
:CONDITION :EQUAL (:VALUE MMUL) 1))

(defrule ($MASS-US-SHAPE-CONTENTS
  > $MASS-US-SHAPE $MASS-US-CONTENTS-ALT
:CONDITION :EXISTS MMUL_1
  > $MASS-US-CONTENTS))

(defrule ($MASS-US-APPEARANCE
  > "The mass wall is well-circumscribed. "
:CONDITION :EQUAL (:VALUE MMUL_1) 1
  > "The mass wall is indistinct. "
:CONDITION :EQUAL (:VALUE MMUL_1) 2
  > "The mass wall is irregular. "
:CONDITION :EQUAL (:VALUE MMUL_1) 3))

(defrule ($MASS-US-CONTENTS
  > "The contents of the mass are solid. "
:CONDITION :EQUAL (:VALUE MMUL_2) 1
  > "The contents of the mass are indeterminate. "
:CONDITION :EQUAL (:VALUE MMUL_2) 2
  > "The contents of the mass are cystic. "
:CONDITION :EQUAL (:VALUE MMUL_2) 3))

(defrule ($MASS-US-CONTENTS-ALT
  > "with solid contents. "
:CONDITION :EQUAL (:VALUE MMUL_2) 1
  > "with indeterminate contents. "
:CONDITION :EQUAL (:VALUE MMUL_2) 2
  > "with cystic contents. "
:CONDITION :EQUAL (:VALUE MMUL_2) 3

```

```

> "."))

(defrule ($MASS-US-RESPONSE
  > "The posterior wall of the mass displays enhancement. "
  :CONDITION :EQUAL (:VALUE MMUL_3) 1
  > "The posterior wall of the mass is iso-echoic. "
  :CONDITION :EQUAL (:VALUE MMUL_3) 2
  > "The posterior wall of the mass displays shadowing. "
  :CONDITION :EQUAL (:VALUE MMUL_3) 3))

(defrule ($MASS-US-SHAPE
  > "The mass appears round "
  :CONDITION :EQUAL (:VALUE MMUL_4) 1
  > "The mass appears ellipsoid "
  :CONDITION :EQUAL (:VALUE MMUL_4) 2
  > "The mass appears irregular "
  :CONDITION :EQUAL (:VALUE MMUL_4) 3))

(defrule ($CONCLUSION
  > $MASS-CONCLUSION
  :CONDITION :EQUAL (:VALUE FINDING) mm))

(defrule ($MASS-CONCLUSION
  > $MASS-MALIGNANT))

(defrule ($MASS-COMPARE
  > "This is a new finding. " $NEWLINE
  :CONDITION :EQUAL (:VALUE MM01A) 1
  > $MASS-CHANGE $NEWLINE
  :CONDITION :EQUAL (:VALUE MM01A) 0))

(defrule ($MASS-CHANGE
  > "It has changed significantly since the last exam. "
  :CONDITION :EQUAL (:VALUE MM01B) 1
  > "It has not changed significantly since the last exam. "
  :CONDITION :EQUAL (:VALUE MM01B) 0))

(defrule ($MASS-MALIGNANT
  > "Impression: There is a " (:VALUE MMRA) "% likelihood"
  " that the mass is malignant. " $NEWLINE
  :CONDITION :GREATER-OR-EQUAL (:VALUE MMRA) 0))

(defrule ($NEWLINE
  > "~%"))

(defrule ($BLANKLINE
  > $NEWLINE $NEWLINE))

(defrule ($TAB
  > "  ")))

```

Appendix F: Description of the Rules for Automated Reports

The following is a more compact description of the rules. We begin with the beginning “nonterminal”, \$REPORT (note all non-terminals begin with the special symbol \$ to more easily distinguish them from terminal symbols). Each nonterminal is expanded using the rules shown in Appendix E until “terminals” are reached. When there are multiple terms in the expansion, they are shown at the same level of indentation in the list (e.g., the \$INTRO is expanded to \$CASE, \$DATE, \$HISTORY and \$COMPOSITION and \$COMPOSITION expands to \$GLANDULAR followed by \$DENSITY)

The terminals are the words that are printed in the report, and thus they don’t expand any further. When there are options in the rules (that is there is more than one expansion of a non-terminal), each option is preceded by a > symbol. If a value is to be read from the database (such as the date or case number), that item is in all capitals (e.g., DATE_C, CASE).

```
$REPORT
$INTRO
  $CASE
    Case CASE
  $DATE
    DATE_C
  $HISTORY
    The present examination is compared to a prior mammogram of DATE_P.
  $COMPOSITION
    $GLANDULAR
      >The breast is almost entirely fat.
      >The breast is largely fat.
      >The breast is largely glandular.
      >The breast is almost entirely glandular.
    $DENSITY
      >The tissue has a low density.
      >The tissue is moderately dense.
      >The tissue is very dense.
  $FINDINGS
    $MASS-FINDINGS
      $MASS-DESCRIPTION
        There is a
      $MASS-NEW
        new
      $MASS-SIZE
        [MAX-VALUE MM06_C MM07_C MM08_C MM09_C] mm
      $MASS-SHAPE
        >round/oval
        >lobular
        >irregular
      $MASS-DISTRIBUTION
        >mass
        >group of similar masses
      $MASS-DANGER
        > with some evidence of spiculation
      $MASS-DANGER2
        and tissue invasion
        > with some evidence of tissue invasion
      $MASS-LOCATION
        >$MASS-POSITION
          > located at the approximate MM03A o'clock
```


\$MASS-DEPTH
 >anterior
 >middle
 >posterior
 position
 > located at the central
 \$MASS-DEPTH
 >anterior
 >middle
 >posterior
 position
 > located at the axillary tail
 \$MASS-DEPTH
 >anterior
 >middle
 >posterior
 position
 \$MASS-SIDE
 > of the left breast
 > of the right breast
 .
 >\$MASS-DEPTH
 >anterior
 >middle
 >posterior
 \$MASS-SIDE
 > of the left breast
 > of the right breast
 .
 >\$ALT-MASS-SIDE
 > located in the left breast
 > located in the right breast
 .
 >.
 \$MASS-CHANGE
 >It has changed significantly since the last exam.
 >It has not changed significantly since the last exam.
 \$MASS-ATTRIBUTES
 \$MASS-SPICULATED
 >A small portion of the margin is spiculated.
 >Some of the margin is spiculated.
 >About half of the margin is spiculated.
 >A large portion of the margin is spiculated.
 >All of the margin is spiculated.
 \$MASS-SPICULATED-CHANGE
 >This is a significant increase from prior examinations.
 >This is a decrease from prior examinations.
 \$MASS-INVASION
 >A small portion of the margin is indistinct due to tissue invasion.
 >Some of the margin is indistinct due to tissue invasion.
 >About half of the margin is indistinct due to tissue invasion.
 >A large portion of the margin is indistinct due to tissue invasion.
 >All of the margin is indistinct due to tissue invasion.
 \$MASS-INVASION-CHANGE
 >This is a significant increase from prior examinations.
 >This is a decrease from prior examinations.
 \$MASS-GLANDULAR
 >A small portion of the margin is obscured by glandular tissue.

- >Some of the margin is obscured by glandular tissue.
- >About half of the margin is obscured by glandular tissue.
- >A large portion of the margin is obscured by glandular tissue.
- >All of the margin is obscured by glandular tissue.
- \$MASS-GLANDULAR-CHANGE**
 - >This is a significant increase from prior examinations.
 - >This is a decrease from prior examinations.
- \$MASS-CIRCUMSCRIBED**
 - >A small portion of the margin is clearly circumscribed.
 - >Some of the margin is clearly circumscribed.
 - >About half of the margin is clearly circumscribed.
 - >A large portion of the margin is clearly circumscribed.
 - >All of the margin is clearly circumscribed.
- \$MASS-CIRCUMSCRIBED-CHANGE**
- \$MASS-MICROLOBULATION**
 - >Microlobulation is present.
 - >There is extensive microlobulation present.
- \$MASS-SKINLESION**
 - The mass
 - \$MASS-SKINLESION-CONFIDENCE**
 - >may be
 - >appears to be
 - >is definitely
 - a skin lesion.
- \$MASS-INTRAMAMARY**
 - The mass
 - \$MASS-INTRAMAMARY-CONFIDENCE**
 - >may be
 - >appears to be
 - >is definitely
 - an intramamary node.
- \$MASS-EXTRAS**
 - >Architectural distortions are evident.
- \$MASS-WC**
 - >Worrisome
- \$MASS-BC**
 - and benign
 - calcifications are present.
 - >Benign calcifications are present.
- >**\$MASS-WC**
 - >Worrisome
- \$MASS-BC**
 - and benign
 - calcifications are present.
 - >Benign calcifications are present.
- \$MASS-ULTRASOUND**
 - An ultrasound was performed.
- \$MASS-US-SHAPE-CONTENTS**
 - >**\$MASS-US-SHAPE**
 - >The mass appears round
 - >The mass appears ellipsoid
 - >The mass appears irregular
- \$MASS-US-CONTENTS-ALT**
 - >with solid contents.
 - >with indeterminate contents.
 - >with cystic contents.
 - >.
- >**\$MASS-US-CONTENTS**

- >The contents of the mass are solid.
- >The contents of the mass are indeterminate.
- >The contents of the mass are cystic.

\$MASS-US-APPEARANCE

- >The mass wall is well-circumscribed.
- >The mass wall is indistinct.
- >The mass wall is irregular.

\$MASS-US-RESPONSE

- >The posterior wall of the mass displays enhancement.
- >The posterior wall of the mass is iso-echoic.
- >The posterior wall of the mass displays shadowing.

\$CONCLUSION

\$MASS-CONCLUSION

\$MASS-MALIGNANT

There is a MMRA% likelihood that the mass is malignant.

Appendix G: Instructions for Mammogram Test Readers

Instructions for Mammogram Test Readers
Harvard Pilgrim Health Care
July, 1997

Greetings! On this page, we researchers from BBN Corporation and the Brigham and Women's Hospital describe your task as you read a set of 150 proven mammograms. The research is supported by the U. S. Army Medical Research and Materiel Command.

Your first time through the set (during July and August) is a "baseline" condition, similar to readings in your usual practice. A second condition (during the winter) provides "enhanced" readings, with a decision aid to be described later. Your personal interest in the baseline condition may derive from your receiving a confidential report of your accuracy relative to the (anonymous) performances of your colleagues. In the enhanced condition, our previous experience suggests that everyone's accuracy will be noticeably improved by the decision aid.

One distinctive aspect of your baseline readings is that you will be reporting a "probability of malignancy" for each case rather than making the usual diagnosis and treatment recommendation. Thus, you will be rating the likelihood of malignancy on a scale from 0 to 100. In short, you will express the chances out of 100 cases that a case exactly like the one at hand will be shown by biopsy to be malignant.

A second distinctive aspect of your readings is that the set of 150 cases contains more malignant cases than you would experience in your usual practice. Specifically, approximately one-third (i.e., about 50) of the cases are malignant. Beyond that, approximately one-third of the cases contain a proven benign lesion. The remaining one-third are defined as "suspicious normals" -- i.e., cases that were recommended for immediate further workup or accelerated follow-up mammograms, but were shown by subsequent examinations over time to be non-malignant. Hence, you may assign somewhat higher probabilities of malignancy to these test cases than you would to a consecutive set of 150 cases in usual practice, in which the number of proven malignancies might be, say, 3 to 5. We perform a statistical analysis of reading performance -- so called ROC analysis -- that gives a measure of accuracy that is unaffected by the proportion of malignant cases in a test set. This measure is also unaffected by the specific way in which the probability scale is used by any given reader, as long as nearly the full scale is used, and is used in a self-consistent manner.

Please ask us any questions you may have now. After a few practice cases, we hope that you will take a reasonably constant approach to all remaining cases.